United States Department of the Interior

NATIONAL PARK SERVICE
Water Resources Division
1201 Oakridge Drive, Suite 250
Fort Collins, Colorado 80525-5596

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IN REPLY REFER TO:

June 12, 2006

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SAND/General

Memorandum

To: Superintendent, Sand Creek Massacre National Historic Site

Through: Acting for William L. Jackson, Chief, Water Resources Division (WRD)
Gary Rosenlieb, Acting Chief, Water Operations Branch, WRD

From: Larry Martin, Hydrogeologist, Water Operations Branch, WRD

Subject: Potential groundwater sources for a potable water supply at the park

I have conducted a thorough search of geology and hydrology reports, water well records, and water quality data for groundwater supplies in the vicinity of the Sand Creek Massacre Site. There are two potential sources for groundwater in the area: the shallow alluvium associated with Sand Creek and the Dakota Sandstone about 1000 feet below ground surface. The intervening bedrock formations are shale and will not yield significant quantities of groundwater.

Groundwater from either source is likely to be poor quality, requiring treatment to meet drinking water standards. Since there is no advantage to drilling a deep well, I recommend constructing a shallow well to obtain groundwater from the alluvium of Sand Creek.

The attached report summarizes the hydrogeology and groundwater quality in the vicinity of the site. If there are any questions regarding this trip report, please call me at (970)-225-3515.

Larry Martin
NPS – Water Resources Division
June 8, 2006

Potential Groundwater Sources for a Potable Water Supply

Sand Creek Massacre Site, Kiowa County, Colorado

The visitor center and administrative site for Sand Creek Massacre will be located along the valley of Big Sandy Creek north of Chivington, Colorado. The USGS conducted a study of the groundwater resources of the Big Sandy Creek Valley beginning in 1959 (Coffin, 1967). The purpose of the study was to determine the availability and chemical quality of groundwater in the area. That report provides much valuable information for assessing potential groundwater supplies in the area. Additional information was obtained from other documents listed in the references section of this report, well records at the Colorado Division of Water Resources, and information from local well owners.

Hydrogeology

In general, most of the area is covered by a thin layer (a few tens of feet thick) of Quaternary deposits–primarily alluvium in the valley of Big Sandy Creek and dune sand in areas beyond the valley. Underlying the Quaternary deposits are Late Cretaceous rocks (approximately 80-85 million years ago). The Cretaceous bedrock formations are relatively impermeable and are generally barriers to downward percolation of groundwater. Precipitation on the land surface infiltrates the permeable Quaternary deposits and accumulates to form a shallow aquifer perched above the impermeable Cretaceous bedrock formations. This conceptual model of the local hydrogeology is depicted in Figure 1 (from Coffin, 1967).

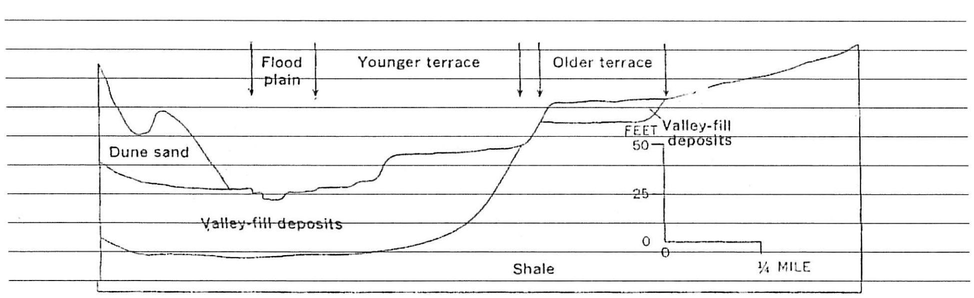


Figure 1. Cross-sectional diagram showing hydrogeology of the Big Sandy Creek Valley.

The Cretaceous bedrock formations—Pierre Shale, Niobrara Formation, and Carlile Shale—are primarily shale but contain a few thin limestone beds. Their combined thickness is several thousand feet. In the immediate vicinity of the Dawson property (T17S, R45W, Sec. 30), the Pierre Shale has been removed by erosion and the bedrock underlying the Quaternary deposits is the Smoky Hill Member of the Niobrara Formation. The Smoky Hill Member is about 700 feet thick and will provide small quantities (less than 2 gpm) of poor quality water in some areas. Underlying the Smoky Hill Member are several more shale formations that are generally impermeable. Any wells completed in the shale formations will likely yield no more than a few gpm of very poor quality water. The Dakota Sandstone is the first dependable bedrock aquifer, but it is at a depth of about 1000 feet and probably contains poor quality water. Therefore, groundwater in the shallow aquifer in the Quaternary deposits is the recommended source for potable water at the Sand Creek site.

The Quaternary deposits are sand, gravel, silt, and clay that have been deposited by wind and streams. The Quaternary deposits can be divided into three groups: 1) terrace deposits which are considerably higher than the stream level (mostly east of Big Sandy Creek), 2) valley-fill deposits along streams, and 3) dune sand, which is generally west of Big Sandy Creek. The Quaternary deposits are the major aquifer, and in fact the only reasonably accessible aquifer, in the area.

The terrace deposits and valley fill along Big Sandy Creek are comprised of sand, gravel, silt, and clay. At the Dawson property they are about 40 feet thick. The sediments show a vertical gradation from very-fine-to-fine gravel and sand near the base to silt and clay or very-fine-to-fine sand near the top.

A series of test wells were constructed along an east-west transect (Coffin, 1967). The transect is approximately parallel with the county road between sections 30 and 31 as shown on Figure 2.

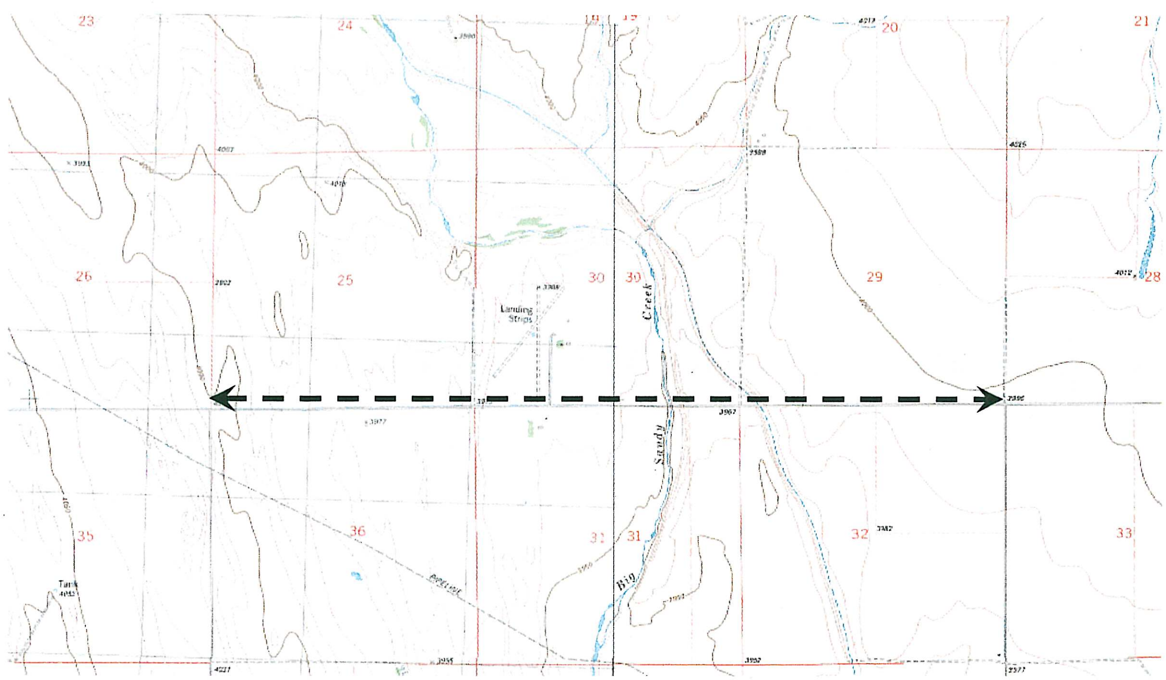


Figure 2. Location of a line of test holes constructed across Big Sandy Creek Valley.

Figure 3 shows the hydrogeologic cross-section based on interpretation of data obtained from the test drilling (Coffin, 1967). The cross section shows that the saturated thickness of the alluvium in the area of interest is probably only about 25 feet. The overlying, unsaturated deposits range from less than 10 feet to more than 20 feet thick. The cross section also illustrates the importance of test drilling (or a geophysical investigation) to identify the variance of the topographical contact between the alluvium and bedrock. The best location for a well would be in the deepest part of the valley, where the saturated thickness of the alluvium will be greatest. This should be balanced with the need to locate the well at a location that is far enough from the creek so that it is not in direct communication with surface water in the creek and at an elevation that is high enough that it will not be flooded.

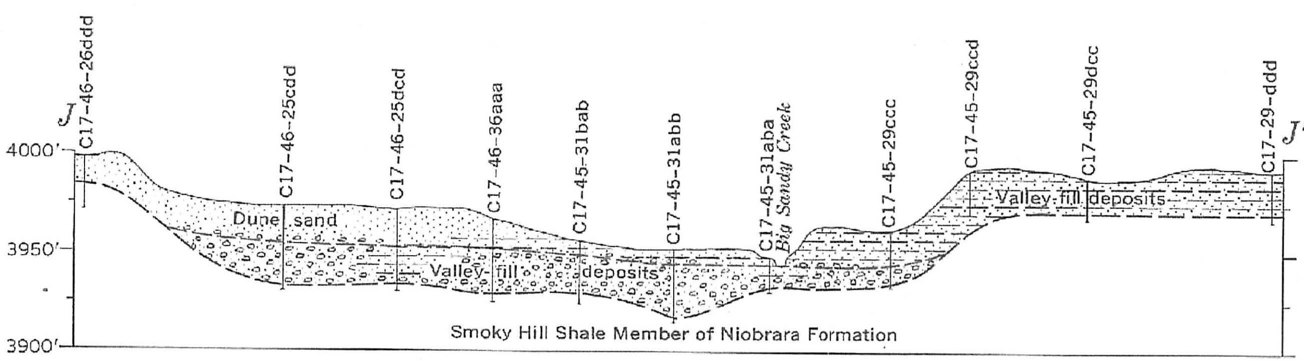


Figure 3. West-East cross-section through the Big Sandy Creek Valley.

The elevation of the water table in the alluvium at the Dawson property was monitored by the USGS from 1959-86 (Figure 4). Water levels were measured monthly for the first five years, then quarterly for two years, and annually from 1968-86. Water levels were fairly constant from about 5-7 feet below ground surface and had no significant trend during the period. This indicates the groundwater supply in the alluvium is being continually recharged, at least on an annual basis, and should be a reliable source for at least small-scale development.

The drawdown and yield of a well at the Dawson property was tested in 1960. The well (17-45-30cbd) was 23 feet deep and had a static water level of 6½ below ground surface. The well was pumped at an average rate of 80 gpm for 24 hours, resulting in 4½ feet of drawdown (Coffin, 1967). This shows there is plenty of groundwater available in the surficial aquifer. However, as will be discussed later, the chemical quality of the groundwater does not meet drinking water standards.

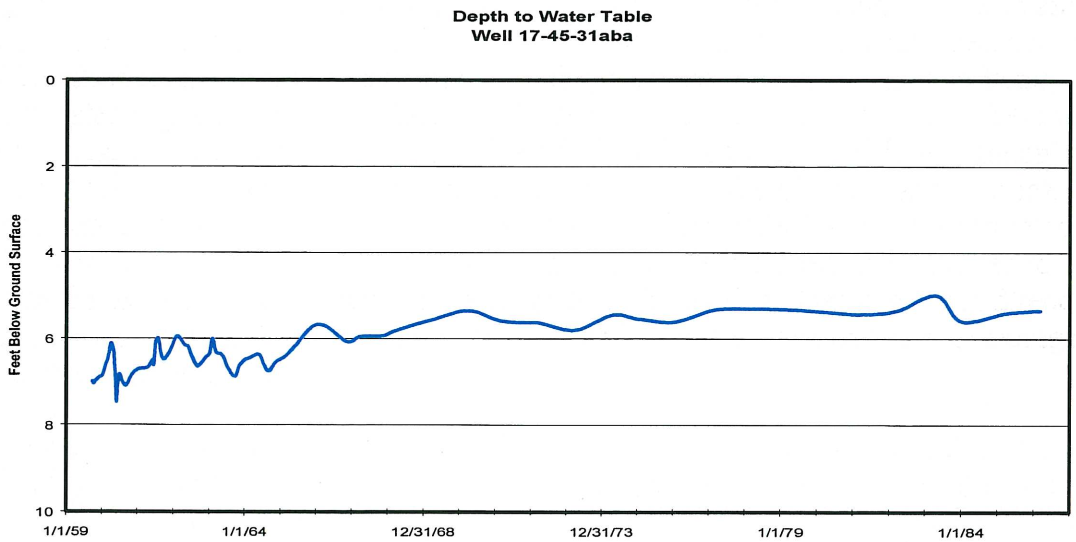


Figure 4. Water level in a shallow well at the Dawson property.

Dune sand covering the area west of Big Sandy Creek is comprised of very-fine to very-coarse sand. Thickness typically ranges from 10-20 feet. Rainfall infiltrates the dune sand and percolates downward until it encounters the impermeable shale bedrock at the base of the dune sand. A very thin perched aquifer forms at the base of the dune, however in most areas the saturated thickness does not allow development of reliable groundwater supplies. Wells constructed in areas overlain by dune sand may go dry during dry seasons.

Water Quality from Shallow Wells

Groundwater in the Quaternary deposits is recharged by infiltration of rainfall. Groundwater flows "downstream" toward the Arkansas River at an estimated 2 feet/day (Coffin, 1967). As the water moves slowly downstream, it reacts with the sediments filling the valley and gradually becomes more mineralized. Water quality becomes progressively worse downstream. The locations of shallow wells which have water quality data are shown in Figure 5.

Chemical analysis of a shallow domestic well (17-45-31aba) along Big Sandy Creek about ½ mile southeast of the Dawson ranch house produced the flowing results (Sept. 21, 1960);

Specific Conductivity	4370 umhos/cm
pH	7.9
Hardness	1100 mg/l
Calcium	269 mg/l
Magnesium	116 mg/l
Sodium	726 mg/l
Potassium	9.6 mg/l
Chloride	135 mg/l
Sulfate	2220 mg/l
Bicarbonate	334 mg/l

Fluoride	1.3 mg/l
Nitrate	1.7 mg/l
Total dissolved solids	3640 ppm

This is a pretty good indication of the water quality that could be expected from a well at the Dawson property. More complete chemical analysis could be obtained by collecting a water sample from one of the existing wells at the Dawson property. Other shallow wells in the area have similar water quality.

Basic water chemistry data from several other wells in the area was obtained from the USGS database (http://waterdata.usgs.gov/nwis/gw). Some of the wells were only tested for specific conductance, which is a general indicator of the overall mineral content of the water. It does not provide information regarding which constituents are most prevalent in the water. Table 1 summarizes the specific conductance of groundwater from wells in the area. All of the wells produce similar, poor-quality groundwater from the unconsolidated deposits associated with Big Sandy Creek.

Table 1. Basic chemical quality of groundwater from shallow wells within about 5 miles of the Dawson property. Well locations are shown on Figure 5.

Well No.	Distance from Dawson Property	Depth feet	Aquifer	Date	Specific Conductivity umhos/cm	Total dissolved solids, mg/l
18-45-18dac	4 miles S	81	VLFL	6/8/61	3170	2570
"	"	"	"	6/6/79	5500	4700
18-45-02ccb	4 miles SE	36	DUNE	4/26/79	3300	
17-45-31aba	½ mile SE	9	VLFL	9/21/60	4370	3640
17-45-16dcc	3 miles NE	60	????	5/2/79	3500	
17-46-15bbd	4 miles NW	27	DUNE	6/8/61	1980	1450
"	"	"	"	6/6/79	2350	1760

VLFL – Valley Fill Deposits
DUNE – Sand Dune

<u>Ground Water Under the Direct Influence of Surface Water</u>

Some people might object to the use of shallow alluvial wells on the basis that they would be classified as being "under the influence of surface water". That claim is incorrect and is often incorrectly stated by persons who do not understand the concept behind the regulations. In order for a well to be classified as being under the direct influence of surface water there needs to be such a direct and immediate hydraulic connection between the groundwater being pumped from the well and the adjacent stream that there is insufficient filtering and travel time between the two to prevent introduction of bacteria and other contaminants from the surface water to the well. Usually this interconnection is first seen as variations in turbidity, temperature, and other basic physical parameters that are directly correlated between the groundwater being pumped from the well and the surface water.

This will not be the case at Sand Creek. The alluvial sediments are sufficiently fine-grained and the distance from a well to the creek would be great enough that there would be a long travel time between the creek and the well. A shallow well near the old ranch buildings would not produce water that could be classified as being under the direct influence of surface water.

Deep wells

Below the shallow water table aquifer, the next potential groundwater source is the Dakota Sandstone, lying at a depth of approximately 1000 feet below ground surface. Intervening geologic formations are primarily shale which are either impermeable or yield only small amounts of very-poor quality groundwater. In recent years, several deep wells have been constructed in the vicinity to obtain water from the Dakota Sandstone. These wells are consistently about 1000 feet deep. An investigation by the USGS in 1979 found only one well in all of Kiowa County that was completed in the Dakota Sandstone (Mustard and Cain, 1981). It was located about 5 miles south of Sheridan Lake. Additional deep wells have been constructed since then. The Brandon Water Association (about 7½ miles southeast of the Dawson property) constructed a water supply well into the Dakota Sandstone in 1980. In 1994, Rex Barlow constructed a well into the Dakota Sandstone at his ranch about 4 miles southwest of the Dawson property. In 1992, Heritage Farms LLC constructed a well completed in the Dakota Sandstone about 7 miles northwest of the Dawson Property. There may be other deep wells constructed or planned for construction. The locations of Dakota Sandstone wells in the vicinity of the Sand Creek Massacre Site are shown on Figure 6.

Water Quality in Deep Wells

Water from wells in the Dakota Sandstone is probably used as the domestic water supply for local ranches that have no alternative source of water. While the water is probably acceptable after a person becomes accustomed to the taste and mineral content, it does not meet current drinking water standards. Additional sampling and testing at some of the newer wells completed in the Dakota Sandstone might be justified to obtain additional data regarding the suitability for human consumption.

Good water quality is obtained from the Dakota Sandstone near the outcrop (recharge) areas to the south, along the Arkansas River valley. Water quality deteriorates as the groundwater flows slowly toward the north-northeast into deeper parts of the basin, leaching minerals from the sedimentary rock.

Water quality data for water from the Brandon Water Association well are available for a limited number of constituents (Craig Newman, pers. Comm.). The water contains high concentrations of sodium (600 mg/l) and sulfate (700-1900 mg/l). Fluoride concentration is also high, 3.7 mg/l. The Brandon well is 7½ miles south of the Dawson property.

Groundwater quality is expected to deteriorate as the water flows from south to north and there is longer contact time of the groundwater with the minerals in the Dakota Sandstone.

Probably the best estimate of water quality from a deep well at the Dawson property can be made by comparison with data from Rex Barlow's well, located 4 miles to the southwest. The sample was analyzed in December 1994 and had the following results:

Sulfate	527 mg/l
Sodium	630 mg/l
Fluoride	2.45 mg/l
Total dissolved solids	1702 mg/l
Specific conductivity	2660 umhos/cm
pH	8.20

The water had very low concentrations of iron and manganese and is very soft (18 mg/l hardness). The high sodium concentration could be a concern for persons on a restricted sodium diet. The combination of high sulfate and total dissolved solids concentration could have a laxative effect on persons not accustomed to drinking it. The recommended limit for sulfate is 250 mg/l and for total dissolved solids it is 500 mg/l. Sulfate content in excess of 250 to 500 ppm (mg/l) may give water a bitter taste and have a laxative effect on individuals not adapted to the water. Fluoride concentrations of more than 2.0 mg/l can darken tooth enamel, causing fluorosis.

Groundwater from the Dakota Sandstone well at Heritage Farms is similar to the water from the Rex Barlow well, but poorer quality. It has nearly 8000 mg/l total dissolved solids, sodium concentration of about 2800 mg/l, and chloride concentration of about 3500-4000 mg/l.

It is fairly clear from the water quality of neighboring deep wells that groundwater from the Dakota Sandstone at the Dawson property would require treatment to make it potable.

<u>Recommendations</u>

My recommendation for developing a potable water supply at the Sand Creek Massacre Site is construction of a shallow well in the valley-fill deposits associated with Big Sandy Creek. There is ample groundwater in the unconsolidated alluvial valley-fill deposits. Sufficient groundwater supplies can be obtained nearly anywhere at the site, but it will be poor quality and require treatment. Available chemical quality data are compiled in this report and can be used to make preliminary estimates of treatment options and costs.

Because of variations in thickness and saturation of permeable sand and gravel and interfingering with fine-grained sediments in the valley-fill aquifer, test drilling is advisable in locating a site for a water supply well. During drilling, the test holes should be logged to identify the thickness of sand, gravel, clay, and silt at each location. The production well should be located at the test hole having the thickest section of saturated sand and gravel and the least amount of clay and silt. Test drilling might be omitted if only a low-yield well (5-10 gpm) is needed. In that case, a well drilled almost anywhere on the property will probably yield sufficient water.

I do not recommend construction of a deep well. Groundwater from the Dakota Sandstone would probably require treatment to meet public health standards. There is no advantage to constructing a deep well vs. a shallow well; both sources will require treatment to meet public health standards. A deep well would be much more expensive to construct, equip, and operate. Groundwater would need to be pumped from about 800 feet below land surface, requiring a large pump and consuming lots of electricity. A very conservative estimate of $100/foot would make the cost of a deep well at least $100,000. A local well drilling company should be contacted for cost estimates for construction of a deep test hole if that alternative is to be pursued further.

There are several old wells at the site that are probably poorly constructed with respect to having proper surface seals to prevent direct flow of surface water down the outside of the well and contaminating the aquifer. All old wells at the site should be inspected, and those wells that are no longer used or present a potential contamination threat should be properly plugged and abandoned.

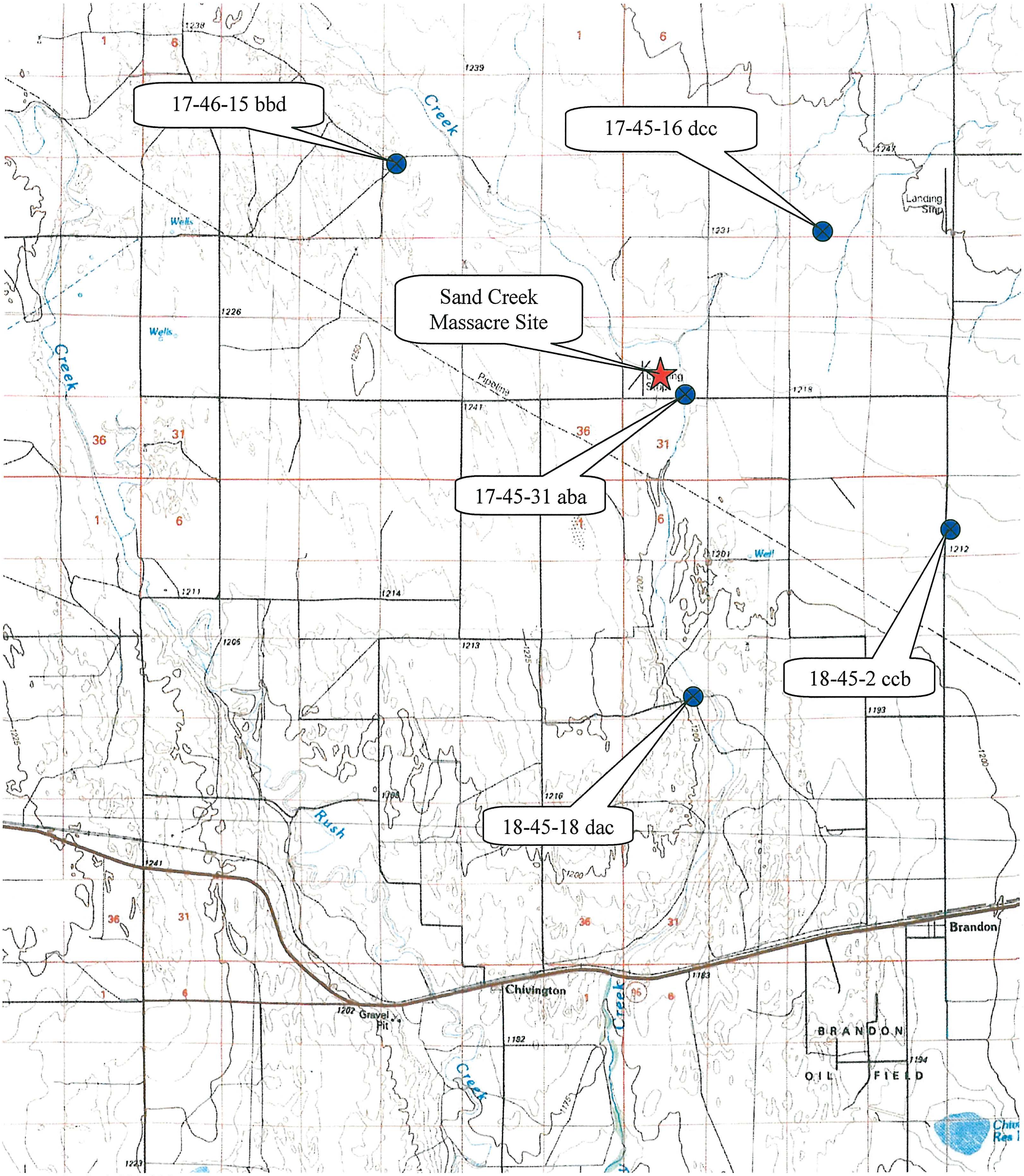
References

Boettcher, Arnold J., 1964, *Geology and ground-water resources in eastern Cheyenne and Kiowa Counties, Colorado*, U.S. Geological Survey Water Supply Paper 1779-N, 32 pp, 3 plates.

Coffin, Donald L., 1967, *Geology and ground-water resources the Big Sandy Creek Valley, Lincoln, Cheyenne, and Kiowa Counties, Colorado*, U.S. Geological Survey Water Supply Paper 1843, 49 pp, 1 plate.

Mustard, Martha H., and Doug Cain, 1981, *Hydrology and Chemical Quality of Ground Water in Kiowa County, Colorado*, U.S. Geological Survey Water-Resources Investigation Open-File Report 81-1023, 2 sheets.

Robson, S.G., and E.R. Banta, 1987, *Geology and Hydrology of Deep Bedrock Aquifers in Eastern Colorado*, U.S. Geological Survey Water-Resources Investigations Report 85-4240, 6 sheets.



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One inch equals 1.578 miles

Figure 5. Location of shallow wells with water quality data in the vicinity of the Sand Creek Massacre Site.

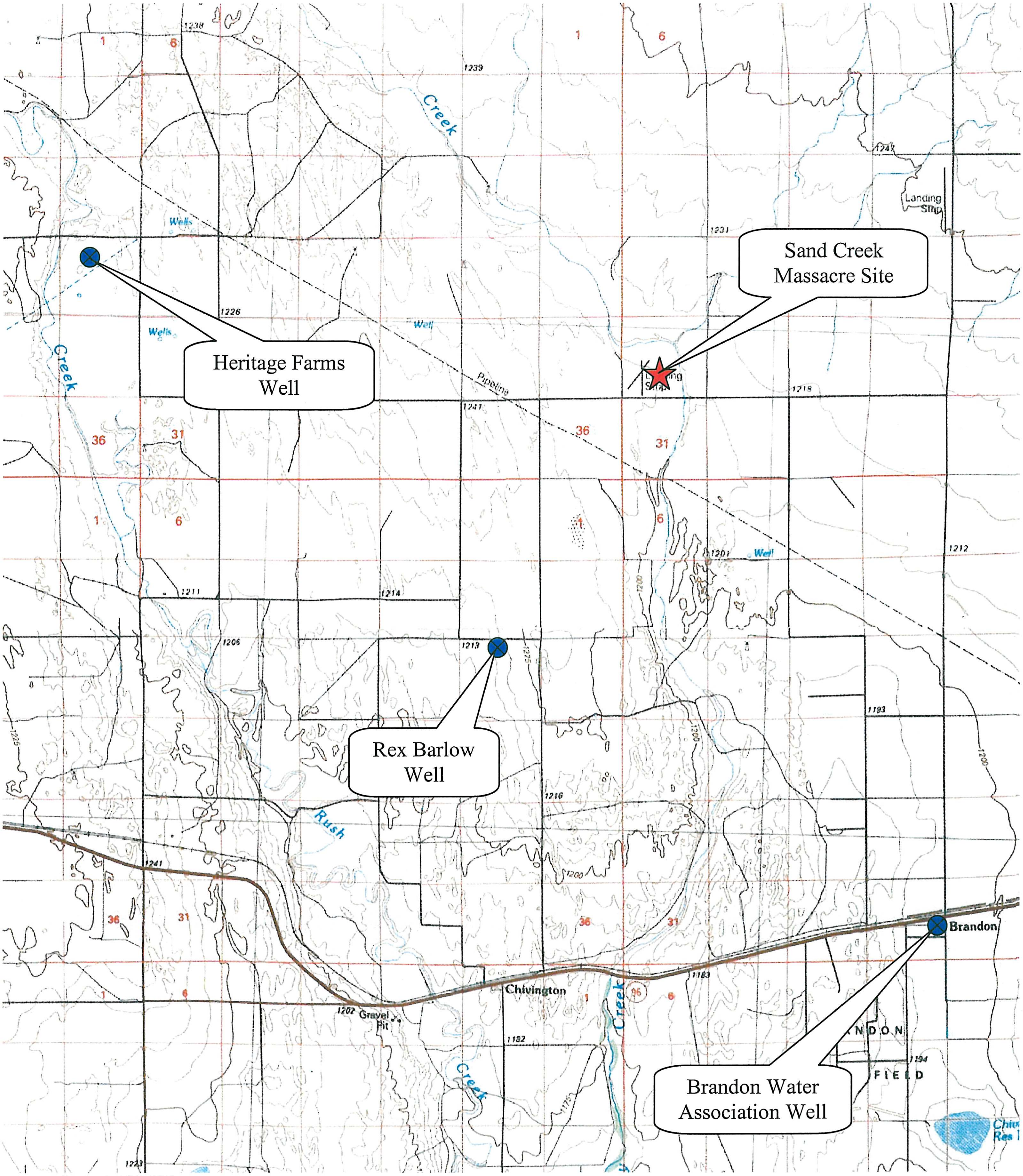

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Figure 6. Location of deep wells completed in the Dakota Sandstone in the vicinity of the Sand Creek Massacre Site.